IMPERIAL MINERAL RESOURCES BUREAU.

THE MINERAL INDUSTRY OF THE BRITISH EMPIRE

AND

FOREIGN COUNTRIES.

WAR PERIOD.

FELSPAR.

(1913–1919.)

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PREFACE

The following digest of statistical and technical information relative to the production and consumption of felspar will constitute a part of the Annual Volume on the Mineral Resources of the British Empire and Foreign Countries.

In this, the first year of publication, an effort has been made to fill in, as far as possible, the hiatus due to the war in the publications relating to mining and metallurgical statistics. Labour, health, and safety statistics have been omitted owing to the difficulty involved in procuring reliable information for the war period, but in future issues these statistics will be included in respect of each year.

Resort will also be had to a much greater extent than at present to graphical representation of statistics of production, consumption, costs and prices.

R. A. S. REDMAYNE,

Chairman of the Governors.

June, 1920.

2, Queen Anne's Gate Buildings, London, S.W.1.

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GENERAL.

Felspars are complex silicates of aluminium and other metals. The chief varieties from the commercial standpoint are :—

(1) potash felspar, including orthoclase and microcline, containing potash as well as alumina ;
(2) albite, containing soda and alumina ;
(3) soda-lime felspars, notably oligoclase and labradorite, containing a mixture of soda and lime as well as alumina.

The following representative analyses show the composition of these different kinds of felspars :—

——	Orthoclase	Albite	Oligoclase	Labradorite
Silica	65·72	68·46	62·30	52·55
Alumina	18·57	19·31	22·00	28·32
Ferric oxide	—	0·28	0·04	2·44
Potash	14·02	—	0·94	0·64
Soda	1·25	11·27	8·20	4·52
Lime	0·34	0·68	4·86	11·61
Magnesia	0·10	—	—	0·48
Totals	100·00	100·00	98·34	100·56

Most of the felspar quarried for industrial purposes is orthoclase or microcline occurring as crystalline masses, or in the form of pegmatite veins or dykes.

In order that a deposit of felspar may be quarried at a profit, its dimensions should be such that work can be carried out by the simplest quarrying methods. Unless there are exceptional transport facilities, it is desirable that a deposit should have a thickness of quite 25 feet. Moreover the felspar should be obtainable free from such deleterious minerals as mica, particularly biotite-mica, garnet, tourmaline, hornblende, apatite and pyrites.

Felspar is utilized chiefly in the manufacture of pottery. Dr. J. W. Mellor informs the Bureau that " in the manufacture of porcelain on the Continent the felspathic flux is introduced mainly as a felspar or felspathic sand. The English porcelain has a flux partly felspar and partly bone ash, where the felspar is introduced with Cornish stone. The Continental hard porcelain is very closely related to the English stoneware and other types of vitreous body used in making insulators, chemical plant, etc."

Ferruginous impurity is objectionable as it discolours the finished product. Quartz may, as a rule, be present up to 20 per cent., but some manufacturers of porcelain specify that the quartz shall not exceed 5 per cent.

The use of potash felspar in the manufacture of glass and particularly chemical ware is steadily growing, and much of the output from Cornwall is used for this purpose.

In addition to its use in the body and glaze of pottery and chinaware, felspar is an important constituent of most enamels used for coating kitchen utensils and other metal wares. It is essential for white enamels that the percentage of iron oxide should be as low as possible, and as a rule not more than 0·5 per cent. of iron is allowed. Iron-enamelled ware is manufactured chiefly in Austria and Germany.

A small amount of low-grade felspar is used in the manufacture of opalescent glass, and the variety usually employed for this purpose is albite (soda felspar).

A little pure-white potash felspar is quarried for the manufacture of artificial teeth, the proportion of felspar used being about 80 per cent., whilst the remainder is quartz with a little colouring and binding matter.

Felspar is used as a flux in the manufacture of emery and carborundum wheels. The mineral must be ground fine enough to pass a 200-mesh or still finer screen.

The waste impure felspar obtained during quarrying operations is ground for use as poultry grit and roofing spar; probably any coarse-grained granitic rock crushed to a 12-mesh would be suitable for these purposes.

Many efforts have been made to extract potash from orthoclase and microcline for use as a fertilizer. Theoretically, pure orthoclase should contain 16·9 per cent. K_2O. Usually the amount of potash in high-grade orthoclase or microcline felspar does not exceed 14 per cent. Most of the processes patented for the extraction of potash are based on the calcination of a mixture of the ground felspar and some salt, such as sodium chloride, or an alkali sulphate, whereby the potash in the spar is converted into a soluble salt and can be recovered by leaching. While many of these patents have proved successful on a laboratory scale, the processes have proved too expensive in practice to allow of potash fertilizers being manufactured from commercial felspar.

A new process for the extraction of alumina from labradorite has recently been introduced in Norway. In this process the felspar is leached with a 30 per cent. solution of nitric acid whereby the aluminium, calcium, and part of the iron are converted into nitrates, the balance of the iron and the whole of the silica remaining undissolved. After removing the iron, the solution is evaporated to dryness, and the residue heated to such a temperature that the aluminium salt only is decomposed. The nitrogen oxides driven off during ignition are collected in the form of nitric acid. It is proposed to use the sodium nitrate and calcium nitrate by-products as fertilizers, and the alumina for the manufacture of aluminium or aluminium salts. The labradorite occurs as large deposits, forming mountain masses in the Sognefjord and Ekersund districts of South-West Norway. The felspar is of good quality and contains about 30 per cent. of alumina.

Felspar is an important constituent of granites and most other igneous rocks, many of which are used extensively for building

and constructional purposes. For ornamental and decorative work, much of the value of the stone depends upon the colours and arrangement of the felspars.

WORLD'S PRODUCTION.

Deposits of felspar of sufficient size and purity, and conveniently situated as regards cheap transport, are not of common occurrence, and are quarried chiefly in Canada, the United States, Norway and Sweden. The " China stone " or " Cornish stone " produced in the United Kingdom consists essentially of partly decomposed felspar.

The United States of America, which has long been the world's chief producer of felspar, consumes the whole of its own output in addition to the greater part of the high-grade felspar produced in Canada.

A large part of the Swedish and Norwegian production is exported to European countries.

During the period under review the world's annual production of felspar, including China stone, has never much exceeded 250,000 tons.

World's Production of Felspar.

(*In Metric Tons.**)

	1913.	1914.	1915.	1916.	1917.	1918.	1919.
United Kingdom† ...	67,714	61,694	40,970	37,473	33,708	37,603	48,651
Canada	15,236	16,388	13,211	17,684	17,661	17,044	
Australia	—	—	—	—	47	—	
Germany (Bavaria) ...	—	3,105	1,970	2,650	2,530		
Italy	—	700	700	900	1,292	1,517	
Norway (exports) ...	40,842	27,967	12,607	12,811	4,435		
Sweden	37,878	20,818	12,105	12,724	18,533	17,850	
United States ...	109,760	122,885	95,388	120,400	128,788	89,670	

* The metric, long, and short tons referred to in this publication are equivalent to 2204, 2240 and 2000 lb. respectively.

† Including China stone.

BRITISH EMPIRE.

United Kingdom.

The bulk of the felspar flux used in the English potteries is obtained from " Cornish stone " or " China stone," a peculiar local variety of granite found in the St. Stephen district near St. Austell in Cornwall.

Cornish stone may for convenience be considered a natural mixture of felspar and quartz, with kaolin, fluorspar, white mica and topaz as accessory minerals. Frequently China stone and China clay occur in the same quarry, and are both worked.

An important feature in Cornish stone is the presence of albite or albite-oligoclase, often fresh and unaltered, in addition to orthoclase.

There are several qualities of China stone on the market, namely, hard purple stone, mild purple, dry white, and buff stone. The differences are due to the varying degrees of alteration; the soft varieties show a greater degree of kaolinization. Typical analyses of hard purple, dry white, and buff stones are as follows :—*

	Hard Purple.	Buff (Cornish).	Dry White.
	Per cent.	Per cent.	Per cent.
Silica	72·28	73·18	73·96
Alumina	14·90	16·13	15·90
Ferric oxide...	0·50	0·52	1·40
Manganous oxide	0·01	0·02	
Lime	1·66	0·61	1·89
Magnesia	0·15	0·14	0·32
Potash	5·25	4·41	4·34
Soda	3·01	2·18	0·45
Water...	0·81	2·01	1·11
Phosphorus Pentoxide	0·53	0·45	
Fluorine	0·88	0·23	
Chlorine	0·02	—	
Titanium dioxide	0·05	0·06	
Lithia	0·02	0·02	
	100·07	99·96	99·37

The proportion of kaolin, felspar and quartz that would go to make up a typical sample of hard purple stone or buff stone would be :—

	Kaolin.	Felspar.	Quartz
Purple Stone	6·7	77·2	16·1
Buff Stone	14·6	55·5	30·9

A small quantity of decomposed granite is quarried in the island of Jersey and used for the same purposes as Cornish stone.

According to reports which have been received by the Bureau from Prof. Grenville A. J. Cole and Prof. P. G. H. Boswell, potash felspar has been quarried during the period under review at Tresayes near Roche, at Kernick near Trevisco, at Trelavour Downs near St. Dennis in Cornwall, and at Castlecaldwell, Co. Fermanagh. Ireland.

Felspar appears not to have been raised elsewhere in Ireland in the period 1913-1919, but many occurrences were investigated in several counties. As a result of these investigations it would seem that the felspar-quartz dykes on the south shore of the Gweebarra Estuary in Co. Donegal, the peninsula north of

* Handbook to the collection of Kaolin &c. in the Museum of Practical Geology by J. Allen Howe. Analysis of "dry white" by Dr. J. W. Mellor (Trans. Ceram. Soc., 1913, **12**, 151).

Portnafrancagh in Co. Mayo, the coast one mile west of Great Newton Head in Co. Waterford, and Castletimon Hill in Co. Wicklow would justify further investigation.

*Output of China stone and Felspar in the United Kingdom.** (*In long tons.*)

	1913.	1914.	1915.	1916.	1917.	1918.	1919.
China stone— Cornwall	66,626	59,752	37,112	36,121	32,196	34,577	43,043
Felspar— Cornwall	—	—	—	—	—	1,986	3,021
Argyll ...	—	—	—	—	—	136	344
Kincardine	—	950	3,200	750	970	300	1,330
Total ...	—	950	3,200	750	970	2,422	4,695†

Canada.‡

Practically the whole of the Canadian production of felspar is obtained from quarries and open workings situated in the Verona district near the town of Kingston on the northern shore of Lake Ontario.

Felspar occurs abundantly in aplite and pegmatite dykes throughout the whole of the provinces of Ontario and Quebec and northward through Manitoba into the North-West Territories. These are mostly, however, either small or too remote to allow of economic working at present.

There are no grinding mills in Canada capable of preparing any considerable quantity of felspar. The whole of the output of high-grade felspar from the quarries is shipped to Ohio and New Jersey, where it is ground and used for the manufacture of pottery and enamelled ware. There is a small grinding plant established at Parham, but it is not equipped with the proper machinery for producing a high-class product. The mill works

* Figures supplied to the Bureau by the Chief Inspector of Mines, Home Office.

† In addition to this quantity, 131 tons of Felspar were obtained from a mine in Co. Fermanagh, thus making a total output of 4,826 long tons of Felspar proper for the United Kingdom in the year 1919.

‡ "Felspar in Canada" by H. S. de Schmid, No. 401, Mines Branch, Dept. of Mines, Canada, 1916.

Annual Reports on Mineral Production in Canada, Dept. of Mines.

Annual Reports of the Ontario Bureau of Mines.

Annual Reports on mining operations in Quebec.

on low-grade felspar, and the output consists wholly of grit used chiefly for roofing purposes.

In the Verona district, the felspar quarried is mainly a high grade microcline, occurring in aplite dykes traversing pre-Cambrian gneisses and crystalline limestones. The felspar is mixed with quartz, and the latter usually occurs in compact masses which are left standing until quarrying operations have removed the felspar, when they are broken down and shipped to the electro-metal works at Welland, Ontario, for the manufacture of ferro-silicon. Deleterious minerals such as tourmaline, pyrites, mica, and hornblende occur in the dykes in varying quantities, but large masses of pure felspar that need very little cobbing or sorting can be obtained. Only the purest mineral suitable for pottery purposes is shipped, and the inferior grades are sent to the waste dump.

The following analyses show the compositions of Quebec and Ontario felspars :—

——	Microcline from Villeneuve mine, Quebec.	Amazonite from Leduc mine, Quebec.	Albite (Peristerite) from Villeneuve mine, Quebec.	Microcline from Richardson mine, Bedford, Ontario.
	Per cent.	Per cent.	Per cent.	Per cent.
Silica ...	64·54	64·42	65·65	64·44
Alumina ...	18·81	18·26	21·65	17·63
Ferric oxide	0·08	0·05	0·46	0·74
Ferrous oxide	0·06	0·03	0·03	0·03
Magnesia ...	0·02	0·01	0·18	0·02
Lime ...	0·57	0·18	1·20	0·40
Soda ...	2·68	3·07	9·87	3·31
Potash ...	13·67	14·16	1·08	13·39
Water ...	0·10	0·10	0·08	0·12
Titanium dioxide	Trace	Trace	Trace	Trace
Manganous oxide	Trace	Trace	Trace	Trace
Strontia ...	Nil	Nil	Nil	Nil
Baryta ...	Trace	Trace	Trace	0·02
Carbon dioxide	Nil	Nil	Nil	Nil

Owing to the low price obtained for high-class felspar and the longer freight haul, the Quebec quarries have not been able to compete with those of Ontario in American markets. The Quebec felspar is similar to that of Ontario and occurs in the same geological formations. The Villeneuve properties, situated 20 miles north of Buckingham, the nearest shipping port, are operated on a mica pegmatite dyke about 150 feet wide, cutting across garnetiferous gneiss. Mining operations are carried out by open cut and drifting into the hill. The deposits are quarried for mica, the felspars microcline and albite being obtained as by-products. Both felspars are white and suitable for the manufacture of high-class chinaware. The microcline can be obtained

in a remarkably pure condition. A few tons of this mineral are quarried annually and used in the manufacture of artificial teeth. Prior to the war, the market value of Canadian potash felspar for pottery purposes did not exceed about £1 per ton delivered at the mill, whereas the market value of "dental Spar," as the pure-white microcline is called, was as high as £4 per ton. Other forms of felspar obtainable in this district are amazonstone, a greenish variety of microcline; and peristerite, a highly iridescent variety of albite. Both these minerals are used in the jewellery and ornamental trades.

Fine specimens of labradorite, a lime-soda felspar. are found near Nain on the Labrador coast. The mineral is used as an ornamental stone on account of its wonderful play of colours, and considerable quantities are collected and shipped for the manufacture of buttons, sleeve-links, scarf-pins, etc.

Production of Felspar in Canada.

Year.	Quantity (short tons).		
	Quebec.	Ontario.	Total.
1913	—	—	16,790
1914	—	—	18,060
1915	572	13,987	14,559
1916	4,610	14,878	19,488
1917	1,188	18,274	19,462
1918	191	18,591	18,782
1919			
	Value ($).		
1913	—	—	60,795
1914	—	—	70,824
1915	2,005	55,796	57,801
1916	18,075	53,332	71,407
1917	8,204	81,622	89,826
1918	4,279	108,449	112,728
1919			

Exports of Felspar from Canada.

Year.	Quantity (short tons).	Value ($).
1913	15,966	62,767
1914	18,072	74,100
1915	*	*
1916	*	*
1917		69,195
1918		101,187
1919		

* Not separately stated.

Australia.*

New South Wales.—The only recorded production of felspar in New South Wales during the period under review was a small shipment in the year 1917 of 21 tons of felspar from Hartley Vale and 25 tons raised from the Valla property, Nambucca Heads.

South Australia.—In the hundred of Dudley, Kangaroo Island, South Australia, felspar and China stone have been mined intermittently for many years. During the period under review output was restricted to a few parcels of China stone and felspar shipped from time to time.

The felspar and China stone occur in a coarsely crystalline granite or pegmatite dyke that traverses altered sedimentary rocks. As far as is at present known the dyke has a length of over 1,000 feet and a width of more than 100 feet. Within the dyke the felspar occurs abundantly, and cubes of this mineral over a foot in size can often be seen. Generally the felspar and quartz are intergrown forming a coarsely crystalline graphic granite. It has been estimated that from one-third to one-half of the dyke consists of felspar and China stone separable by hand-picking.

The following analyses are representative of the material available in the hundred of Dudley :—

	Per cent.	Per cent.
Silica	70·20	66·10
Alumina	18·90	20·28
Ferric oxide	1·02	0·84
Magnesia	Nil.	Nil.
Lime	0·08	0·12
Soda	2·58	2·58
Potash	5·74	8·76
Water	0·67	0·50

FOREIGN COUNTRIES.

Norway.

Prior to the war Norway produced about 40,000 tons of felspar rock annually. The mineral quarried is a very pure potash felspar, occurring in large irregular masses and pegmatite veins traversing gneiss. The quarries are situated near Hundholm, Bergen, Stavanger, Kristiansand, Narvik, Bodo, and in many other localities, notably near Mosken in the Lofoten Islands.

Practically the whole of the felspar quarried in Norway is exported, principally to Germany, Belgium, Great Britain, and Russia. Most of the felspar used in the Royal Porcelain Works, Copenhagen, is obtained from the Naresto quarry, between Tvedestrand and Arendal.

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* Annual Report Dept. Mines, N.S.W., 1917. Rev. Min. Oper. in S. Australia, January to June, 1917 : No. 26.

Sunstone or aventurine spar is quarried to a small extent at Tvedestrand, and is used for the manufacture of fancy buttons, sleeve-links and other such articles.

Mention may be made of the beautiful Norwegian syenite known as laurvigite, which is used largely in Great Britain for decorative building purposes, on account of the play of colours it shows on polished surfaces. The rock is quarried from the Laurvig and Frederiksvaern districts, and consists chiefly of felspar.

The following is an analysis of Norwegian felspar reported by H. Seger (Gesammelte Schriften, Berlin, 415, 1896) :—

	Per cent.
Silica	64·98
Alumina	19·18
Ferric oxide	0·33
Lime	Trace
Magnesia	0·25
Potash	12·79
Soda	2·32
Loss on ignition	0·48

*Exports of Felspar from Norway.**

Year.	Quantity (metric tons).	Value (£).
1913	40,842	34,140
1914	27,967	25,054
1915	12,607	12,097
1916	12,811	14,892
1917	4,435	10,108
1918		
1919		

Sweden.

Sweden possesses many important deposits of felspar rock. Formerly, the felspar was obtained chiefly from Ytterby pegmatite on the Island of Resar, but this district does not at present produce any important quantity. The bulk of the Swedish output of felspar is obtained from the quarries at Kolsva in the Vestmanland district, Margretelund in the Stockholm district, and Dröm in Ostergotland. In the Island of Ouest on the south-west coast there are many large outcrops, very few of which are worked. Other important deposits are worked in the coast section around Luleä and Ranea in Norbotten.

Very little of the felspar produced is consumed in domestic potteries and the greater bulk of the output is shipped to European porcelain works in crude lump form. There are only two felspar grinding mills in Sweden, one at Klinktjärn, near Kolsva,

* Norges Bergverksdrift. Value converted to £1 sterling at the rate of 18·6 Kroner = £1.

operating on a low-grade graphic granite containing about 20 per cent. of quartz, and the other at Baldersnäs, near Stockholm.

The following analyses of Swedish felspar are quoted by W J. Furnival (Leadless decorative tiles, etc.; Stone, 331, 1904) :—

	Per cent.	Per cent.
Silica	64·40	65·30
Alumina	19·30	19·71
Ferric oxide	0·30	0·64
Lime	0·40	0·68
Magnesia	—	0·18
Potash	12·55	8·81
Soda	2·58	7·32

*Production of Felspar in Sweden.**

Year.	Quantity (metric tons).	Value £
1913	37,878	18,312
1914	20,818	10,730
1915	12,105	6,705
1916	12,724	6,747
1917	18,533	14,213
1918	17,850	15,558
1919		

Imports of Felspar to Sweden.†

Year.	Quantity (metric tons).	Value £
1913	172	379
1914	25	49
1915	32	209
1916	200	392
1917	191	539
1918	96	812
1919		

*Exports of Felspar from Sweden.**

Year.	Quantity (metric tons).	Value £
1913	38,072	41,837
1914	16,845	15,991
1915	10,703	10,016
1916	13,820	12,774
1917	14,112	15,003
1918	15,854	16,266
1919		

* Bergshantering Berättelsee av Kommerskollegium (Annual). Value converted to £ sterling at the rate of 18·2 Kroner = £1.

† Statistisk Årsbök for Sverige. Value converted to £ sterling at the rate of 18·2 Kroner = £1.

United States of America.*

The United States is the greatest producer of felspar in the world.

Prior to the war, there were about 50 quarries operating in the States of Maryland, New York, Virginia, North Carolina, Maine, and Connecticut. There are few, if any, large producers of high-grade felspar. Most of the larger properties operate on low-grade material. Felspar deposits in the United States are usually opened up to obtain the pure mineral known as dental spar, and when no more of this material can be obtained, the high-grade felspar is quarried and sold to operators of low-grade material. In course of time, with the exhaustion of this better-class material, the quarry either closes down or buys high-grade material from some newly opened quarry to mix with its low-grade product.

The felspar quarried in the United States is chiefly the potash variety, but most quarries yield some soda felspar. Much of the material quarried by the larger producers is a coarse-grained granite carrying a nearly constant proportion of quartz and felspar. A typical quarry yields a product containing about 70 to 80 per cent. of felspar, the remainder consisting of quartz.

The great bulk of the crude and ground high-grade felspar is sent to the chief pottery centres at Trenton, New Jersey; and East Liverpool, Ohio. Other important potteries are situated at Philadelphia and Toughkenamon, Pennsylvania; Syracuse, New York; Coshocton, Ohio; and Chester and Wheeling, Virginia.

In addition to the domestic production of felspar, the United States imports almost the whole of the Canadian production and a considerable tonnage of Cornish stone from Great Britain. Very little Norwegian or Swedish felspar is imported.

Prior to the war, the cost of mining felspar at most American quarries would run from $2 to $2.50 per long ton for high-grade minerals. As the selling price for crude felspar at that date was not more than $3·31 per ton and $8·31 for ground material, it was essential that transportation should be kept as low as possible. A haul of more than two or three miles to the railway would render most of the low-grade deposits unprofitable.

Felspar Sold by Producers in the United States.

Year.	Crude.		Ground.		Total.	
	Quantity (short tons).	Value. ($)	Quantity (short tons).	Value. ($)	Quantity (short tons).	Value (†) ($)
1913	45,391	148,549	75,564	628,002	120,955	776,551
1914	85,905	263,476	49,514	366,397	135,419	629,873
1915	—	—	—	—	105,118	489,223
1916	—	—	—	—	132,681	702,278
1917	—	—	—	—	141,924	728,838
1918	—	—	—	—	98,816	674,745
1919						

* Annual Reports on Mineral Resources of the United States.
(†) Value as sold (crude and ground).

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